MICHIGAN ENVIRONMENTAL SCIENCE BOARD

INDOOR AIR INHALATION INVESTIGATION PANEL
MEETING SUMMARY
THURSDAY MAY 4, 2000
COURTYARD BY MARRIOTT
7799 CONFERENCE CENTER DRIVE
BRIGHTON, MICHIGAN

PANEL MEMBERS PRESENT
Dr. Lawrence Fischer, Chairman
Dr. Ralph Kummler
Dr. Linda Abriola
Mr. Keith G. Harrison, Executive Director

MDEQ/OSEP SUPPORT STAFF PRESENT
Mr. Jesse Harrold, Environmental Officer

I. CALL TO ORDER

Dr. Lawrence Fischer called the meeting of the Michigan Environmental Science Board (MESB) Indoor Air Inhalation Investigation Panel (Panel) to order at 8:05 a.m.

II. EXECUTIVE DIRECTOR'S UPDATE

Mr. Keith Harrison indicated that he did not have an update to provide for the meeting.

III. PRESENTATION BY IAN HERS

Mr. Ian Hers indicated that he was involved in research at the University of British Columbia (UBC), as well as working with Golder and Associates (Golder) on a part-time basis. He noted that his initial background was in hydrogeology and geotechnical engineering, until becoming interested in environmental contamination. Working with the Minister of the Environment in British Columbia, Mr. Hers has been involved with a field validation study of a risk-based approach to contamination regulation.

Mr. Hers note that at many sites, screening level model predictions suggest significant risk from indoor air concentrations. However, there are only a few sites with quantified effects on indoor air quality and few high quality field based studies for chlorinated solvents contamination. There are also limited data evaluating pressure-driven advective flow at such sites. Other key issues include the role of biodegradation in vapor attenuation for petroleum hydrocarbon sites, model sensitivity and appropriate input parameter ranges, and a protocol to guide the use of screening models.

The Golder/UBC research program was initiated because provinces in Canada were implementing a risk-based corrective approach with a high level of uncertainty for the soil vapor to indoor air pathway. Model validation was needed, with a more complete

understanding of soil vapor fate and transport, and intrusion of vapors into buildings. The goal was to collect as much high-quality field data as possible to validate predictive models, evaluate existing models, and develop new screening and numerical models as well as protocols for this pathway. This would lead to improved models and greater certainty. The project approach included identification of factors affecting the pathway, selection of a relatively simple field site, conduction of a multi-year field monitoring program, and construction of a building with controlled properties.

The site chosen was Chatterton, British Columbia, a former petrochemical plant contaminated with benzene, toluene, and xylene. Subsurface conditions consisted of a thin silt, fine sand crust, underlain by about 10 feet of medium sand. The building constructed was a 6 by 9 meter greenhouse, which was less expensive than a regular house, but quite adequate for the purpose. Field validation testing included groundwater and soil gas chemistry; physical properties such as moisture content, porosity, grain size, and water retention, organic carbon, and nutrients; subslab oxygen, pressure and temperature; weather; soil-air permeability, and push-pull diffusion testing using a helium tracer. There was foundation characterization and concrete testing, with flux chamber tests for volatile organic compound (VOC) intrusion through the slab at various depressurizations, and testing of indoor and outdoor air concentrations. One significant pathway for vapor intrusion is an edge crack that can develop between a building slab and the foundation wall. For this site, steel inserts were used to control the edge crack.

The framework for a conceptual model of diffusion differs depending on whether the source of contamination is in the soil above the water table, or comes from a hydrocarbon plume below or at the water table. Another type of conceptual model is to look at the far-field, or Vadose zone compartment where the important parameters are moisture content and biodegradation rate, as opposed to the near-field, or building foundation and subsoil compartment where advection is a critical issue. While there are a number of screening models, they are based on the Johnson and Ettinger (J&E) model, with the exception of analytical models such as the Jury model, which considers aqueous-phase advection, or the Domenico model, which considers gas-phase advection. One difficulty with the various models is assumption of a dirt floor rather than the concrete slabs, which are more typically found. The J&E model deals with diffusion in soil, as well as diffusion and advection through the concrete slab. The existence of possible source depletion also needs to be considered in choosing a model for small amounts of contamination.

Contaminant movement through the building foundation assumes diffusion through dirt-filled cracks, using estimated crack ratios relative to the total foundation area. Various models use differing moisture contents as well as variable total porosity. An important point is that if the crack ratio is too low the predicted diffusive flux may be inappropriate.

Regarding advection, although some models use the Hagan-Pouisselle relationship for laminar flow through parallel plates, the J&E model uses the analytical equation for flow through a horizontal drain. The perimeter crack model is most sensitive to soil

permeability, but is also influenced by the foundation properties, and the foundation model is solely dependent on the foundation properties. One equation that can be used to predict flow into a structure is the equivalent leakage area, used for radon studies. It is a simple equation, seen in standard civil engineering textbooks. However, the equivalent leakage area is not equivalent to the crack ratio used in the J&E model and cannot be used interchangeably.

One thing that the J&E model seeks to predict is the vapor attenuation ratio, which is the indoor air concentration divided by the source soil gas concentration. This ratio is affected both by soil properties and the building properties. Possible values have been determined according to varying properties and situations. Based on estimated probability distributions for a reasonably well-characterized site, the uncertainty ranges from about one to two orders of magnitude. Certain parameters for the J&E model are particularly sensitive. These include the source concentration, depth to contamination, and soil properties such as air-filled and total porosity, soil organic carbon fraction, and capillary fringe thickness. Other sensitive parameters for the J&E model are the foundation and sub-soil properties as well as building properties such as mixing height and ventilation rate. If there is a deep source of contamination, the soil properties are more critical; however, if the contamination is shallow, the crack ratio and building foundation properties are most important.

There are a number of approaches to model validation including qualitative evaluation of vapor profiles. It is possible to examine individual processes, isolating things like diffusion, biodegration, and advection. Soil gas intrusion can also be measured using a tracer, or estimating from radon concentrations. However, applying results of radon studies to VOCs can be problematic as there are different boundary conditions and possible diffusive resistance is not taken into consideration. Another method of model validation is to directly measure indoor air concentrations. Direct measurements of VOCs in indoor air were done at various sites, including Chatterton, British Columbia; Alameda, California, as well as at sites in Massachusetts and Colorado.

The J&E model gives information on predicted vapor profiles and diffusion. Typically, diffusion through the slab is at a lower rate than in soil. One site in Chatterton showed bio-attenuation of about 0.5 to 0.8 meters depth. Findings were supported by tests of oxygen and carbon dioxide concentrations, as well as some lab testing. Rates were comparable with other studies, such as the one by George DeVaulle. There were some seasonal effects with slightly higher oxygen concentrations seen in the summer. Temperature and barometric changes also affect biodegradation. Diffusion can be predicted by the Millington and Quirk relationship. Lab tests have shown this to be an accurate measuring tool, but results of field tests have been less consistent.

Regarding measured intrusion rates, there can be significant pressure coupling between the building and the soil, and pressure gradients can extend several meters. Radon studies have indicated that as depressurization increases, advection becomes more important than diffusion. Comparison of J&E predicted soil gas intrusion with measured concentrations shows perhaps an order of magnitude difference. At

Chatterton, natural diffusion was examined as well as that seen with various levels of depressurization with two methods used to estimate the VOC flux. For natural diffusion the indoor and outdoor concentrations are similar, but at 10 and 30 pasquels, there is a significant difference. The outdoor air was measured near the building at a height of one and a half meters. Edge cracks and untrapped drains were the most significant source of air contamination, but hairline cracks were also seen to be contributory.

The J&E model has been noted to under predict what is going on with diffusion, but when advection is considered it is more conservative and might over predict. Factors such as earthen floors, highly-cracked concrete floors, or lack of biodegradation will lead to increased problems. However, these impacts can be lessened by ventilation. At the site in Colorado, Paul Johnson calculated the attenuation ratio to be 1×10^{-5} while Robbie Ettinger used the J&E model to estimate a slightly higher, and more conservative, value of 8.3×10^{-5}. This was sensitive to capillary fringe, building properties, height and ventilation rate.

One conceptual framework for the use of models for the soil vapor to indoor air pathway involves a tiered approach. Tier 1 is the diffusion only model, tier 2 is diffusion and advection through the slab, and tier 3 allows use of more sophisticated models and risk management practices. Shallow contamination or preferential pathways might result in a tier 0 situation with immediate action taken to mitigate the problem. Deep contamination with low diffusion potential could be a pathway off-ramp, as there is very little potential for significant intrusion into buildings. The J&E model is considered tier 2.

In order to confirm whether the J&E model is appropriate, several factors need to be considered. Good site characterization includes definition of the contamination source including depth, distribution and extent, as well as determination of the advection potential through the soil and through the slab. Drain tiles can also have an impact on infiltration and could be an important consideration in addition to the slab. Ventilation includes natural ventilation through windows and doors, and mechanical ventilation. Ventilation is generally increased in the summer and decreased in the winter, but the current trend is for energy efficient homes with decreased ventilation rates. This could be important as there are also VOCs in building materials and consumer products.

IV. PANEL DISCUSSION

Dr. Kummler noted that in the studies discussed where the J&E model was applied, the input parameters had been reasonably well defined. He then asked if Mr. Hers had an opinion on a generic model where the uncertainty would be greater. Mr. Hers replied that it would depend on the quality of data available, and that there needs to be some level of site characterization and basic knowledge to use the model. Values should be within appropriate ranges for key input parameters with site-specific data needed for key sensitive parameters such as moisture content. Mr. Andy Hogarth (Michigan Department of Environmental Quality - MDEQ) noted that it would be difficult for Mr. Hers to determine the appropriateness of using the model for generic criteria without knowing how the generic criteria are used in a regulatory structure. For example, there

are situations in which the criteria are not applicable, or facility-specific data are used. There are also situations where limited cleanup options are available. Mr. Hers added that generating entirely generic criteria for soil and groundwater is very difficult. He stated that he would advocate an approach with some screening of sites, and then a combination of site-specific data and some default parameter ranges plugged into a model to determine risk of indoor air concentrations.

Mr. Grant Trigger (Michigan Chemical Council) asked for clarification on variation of parameters in the Monte Carlo simulations that Mr. Hers had conducted. Mr. Hers stated that he had varied all the parameters in the J&E model including source concentration, soil properties, and building properties. At a fairly typical site with rather shallow contamination, sandy soils and moderate depressurization, there was perhaps one to two orders of magnitude range from the 5th to the 95th percentile. Mr. Jeff Crum (MDEQ) asked for definition of the high and low moisture values used. Mr. Hers replied that for a low moisture content, the air-filled porosity was 0.2, and for the high moisture content, air-filled porosity was 0.1. Dr. Abriola noted that this was a fairly narrow range.

Mr. Trigger noted that changing building trends have included the requirement for a vapor barrier beneath the slab for the purpose of avoiding sweating on the slab. He questioned whether this would also have a benefit of reducing flux or vapor intrusion. Mr. Hers replied that some sites with these vapor barriers had shown a small decrease in radon intrusion, but this could be difficult to quantify and should not be relied on.

Dr. Kummler asked for clarification on instances where the model would not be valid. Mr. Hers answered that although it was difficult to be definitive, contamination sources within a meter of the basement could have the potential for significant depressurization. As the model does not take into account advective transport in the soil itself, this would not be an appropriate site to use the model. Dr. Kummler noted that although the model might under predict the exact values, it would likely still indicate a problem.

Mr. Hers was asked if it would be beneficial to vent the existing negative pressure to the outside. He replied that one approach would be a passive, or sub-slab, system of depressurization. This could be done with perforated pipes below the building that could vent in various ways. Some studies suggest that passive depressurization will reduce soil gas intrusion to a small extent, and significantly reduce radon intrusion. Dr. Abriola commented on the Colorado site, which had a very low attenuation value but still had significant problems with indoor air quality. Mr. Crum replied that the chemical of concern at that site was 11-dichlorylethylene, which is highly toxic and volatile. So, although there was substantial attenuation, a significant toxic effect remained.

V. PRESENTATION BY MR. GRANT TRIGGER

Mr. Trigger stated that he serves as General Counsel to the Michigan Chemical Council, as well as participating on the MDEQ Part 201 Advisory Group. He stated that the purpose of his presentation was to share some perspectives of the regulated community members who have participated in the Part 201 Work Group over the past

two to three years. He noted that there has been significant dialogue between various interest groups, the regulated community, and the MDEQ in development and implementation of various administrative rules, including guidance on a risk-based approach to cleanup criteria. However, with the indoor air issue, there have been differences of perspective that have led to the request for mass media review of this issue.

Some of the original discussions regarding indoor air involved the possible existence of a generic pathway, and how to evaluate the problem. There was substantial concern from the regulated community that the J&E model needed validation, with questions as to whether this model could be applied to generic criteria. There was also significant effort made among the MDEQ Part 201 Working Group to review the parameters that are used by the MDEQ to calculate indoor values. A fundamental concern, however, is the question of when is indoor air an issue that needs evaluation. Less than one percent of the hundreds of sites evaluated by the MDEQ in 1997 were noted to have a problem.

Approximately six years ago, guidance documents were developed that established land use based criteria including industrial, commercial and residential criteria. Also, there were relevant generic pathways identified including groundwater, drinking water and soil pathways. This began the process of creating generic criteria based on types of land use and exposure pathways. Michigan has been in the forefront in addressing these issues and has developed a reputation for being innovative and creative. However, there is a concern that the indoor pathway is beyond the capability of generic criteria due to the variability of individual sites. With 40 parameters being considered in the J&E model, the complexity of the modeling process is too great. Also, the process deals with predicted results, not actual indoor air measurements.

One purpose of generic criteria is to create a more streamlined administrative process. However, there is concern that the current regulatory programs create an unrealistically high expectation of indoor air problems, with too many sites being referred for evaluation. There is concern that a solution cannot be defined for indoor air issues without better clarification of the existence and/or extent of the problem. It might be very useful to do additional field tests on sites under evaluation by the MDEQ to determine whether measured results are similar to those predicted. In considering the J&E model, there is agreement that the mathematical formula is reasonable, as are the assumptions, but the number of parameters makes it difficult for sites to exactly match the required specifications. The model might be better used as a tool for screening rather than for generic criteria purposes. Also of concern is inadequate consideration of factors such as lateral migration of contaminant, bioremediation, and source depletion.

An alternate approach would be to have a screening procedure to define those sites more likely to have a problem that needs to be addressed. Items of concern would include perforated drain tiles, a highly concentrated dissolved plume in close proximity, and free product. However, exceeding screening levels does not automatically indicate a problem. The concept of an on-ramp/off-ramp approach acknowledges the presence

of circumstances where the model is likely to either under predict or over predict the extent of the problem. The difficulty is in delineating the threshold between needing detailed evaluations of sites and deciding that concern is not warranted.

VI. PANEL DISCUSSION

Dr. Kummler asked whether the term “generic” had specific significance, as opposed to discussing a screening or decision-making tool. Mr. Trigger replied that deciding whether a model is to be used as part of criteria or as a screening tool has legal implications. Contamination values in excess of criteria would be a violation whereas values in excess of a screening value would simply be an element in the decision making process. Mr. Hogarth noted that the generic criteria have greater regulatory weight than screening criteria, however, there are many options for using other criteria that might be more appropriate for a specific site. So, exceeding the generic criteria does not automatically mean that a site is in violation of the legal standards. Mr. Hogarth also noted that the indoor air criteria were set relatively high and violations would likely be apparent from other pathways before problems were noted in the air.

Dr. Abriola asked if Mr. Trigger had documentation of the high false positive rate that he had indicated could be expected, and whether he had any alternative methodology to propose. Mr. Trigger replied that most of the data was anecdotal in nature, but he would try to get further information, and would also get something in writing for the Panel that discussed what might be a better process to follow. He reiterated his opinion that when the problem was adequately defined, the solution would soon follow. Dr. Kummler stated that the problem was fairly clear in that at times the public would need protection from the indoor air pathway. The question is in the exact values which would be protective, and which flow diagram could be used to determine those values.

Dr. Fischer asked for the number of cases that had used generic criteria. Mr. Hogarth replied that from 1997 through 1999, more than 110 remedial action plans had been approved, with only 12 sites exceeding the criteria. In addition, most of those approved met generic residential criteria, meaning all the pathways were considered, some of which were more restrictive than the air pathway. In certain cases with groundwater contamination, remediation of this component was also protective of the air. Mr. Trigger noted that it was necessary to determine how many of the 12 sites not approved had actual indoor air concentrations in excess of the criteria. This would correlate prediction to actual risk. Mr. Hogarth answered that several cases were denied due to insufficient information and that other sites did not have buildings, and so indoor air was not an issue.

V PUBLIC COMMENT

Mr. Mark Toman (Ford Motor Company) noted that not a lot of time had been spent on researching whether the indoor air pathway is an issue. This had been assumed and discussion had focused on the J&E model and its parameters. He questioned whether this assumption was accurate. Mr. Trigger added that the regulated community felt that

soil and groundwater regulations had been appropriately based on measured concentrations and direct exposure pathways, but there was not the same level of confidence or direct connection found with the air inhalation pathway.

VI. PANEL ASSIGNMENTS

Mr. Harrison noted that writing assignments had been determined at the last meeting, with reminders sent out. He added that he would promptly forward any substantiating data received from presenters at this meeting, or from other sources, to all Panel members.

IX. ADJOURNMENT

The meeting was adjourned at 12:30 p.m.

Keith G. Harrison, M.A., R.S., Cert. Ecol.
Executive Director
Michigan Environmental Science Board